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INDIVIDUAL JOINT CONTRIBUTIONS TO FORWARD PROPULSION DURING TREADMILL WALKING IN WOMEN WITH HIP OSTEOARTHRITIS

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Abstract

Introduction: Hip osteoarthritis (OA) is a prevalent degenerative joint condition that significantly impacts mobility and quality of life, especially among women.

Objective: The main objective of the study is to find the individual joint contributions to forward propulsion during treadmill walking in women with hip osteoarthritis.

Methodology: This observational study was conducted at Department of Orthopaedic Surgery Jinnah Medical &Dental College Karachi during March 2022 to March 2023. A total of 25 women diagnosed with hip OA were recruited for this study. Inclusion criteria required participants to have a confirmed diagnosis of hip OA based on clinical and radiographic assessments, with symptoms including joint pain, stiffness, and reduced range of motion.

Results: The study included 25 women with a mean age of 58.4 years (±5.8), ranging from 55 to 70 years. Participants had a mean BMI of 27.6 kg/m² (±3.1), indicating a moderately overweight population, with a weight range of 60 to 85 kg. The average walking speed was 1.08 m/s (±0.15), slightly below the typical speed for healthy individuals. Clinical assessments revealed moderate pain and functional impairments, as reflected by a mean WOMAC pain score of 15.4 (±4.3) and a function score of 22.1 (±6.8). Participants reported an average VAS pain score of 6.2 (±1.5), indicating moderate discomfort during walking.The hip joint contributed 22% to forward propulsion, showing an 18% reduction compared to healthy controls, primarily due to decreased power generation during the late stance phase. In contrast, the knee joint's contribution increased by 22%, accounting for 34% of the propulsion, highlighting compensatory overloading to offset the reduced hip function.

Conclusion: It is concluded that women with hip osteoarthritis (OA) exhibit significant alterations in joint contributions to forward propulsion during treadmill walking. Specifically, the hip joint demonstrates reduced power generation, which is compensated by increased knee joint contributions, while the ankle joint maintains its typical role in propulsion.

Introduction

Hip osteoarthritis (OA) is a prevalent degenerative joint condition that significantly impacts mobility and quality of life, especially among women. This is a disease that affects the normal movement of joints and as a result of the affected joints being swollen, painful and stiff, people develop new walking patterns [1]. Appreciation of individual joint contributions to the forward propulsion during walking in hip OA patients is essential in designing specific approaches towards managing the disorder. Gait propulsion as a fluid and complex movement includes the hip-knee and knee-ankle joint moments as critical elements for providing the mechanical energy driving the lower limbs forward [2]. In patients with hip OA the hip joint may not function adequately and may contribute to the less effective movement strategies which could cause increased demands on other areas and, therefore, increased hip joint pain or additional musculoskeletal conditions. Such compensatory strategies may present in reduced hip joint power, increased dependence on knee extensors, or adaptations in the ankle push-off movement. When and how such changes happen needs to be established to effectively manage the functional impairments due to hip OA [3].

The motion of gait is half-jeanous and involves the intricate interaction of various joint in order to facilitate smooth gait. In healthy people the hip acts as a major contributing joint during stance phase and the ankle joint in push-off phase [4]. The knee joint also records an assisting function in transferring energy between the hip and ankle joint. In women with hip OA pain and joint deterioration can intervene to change the load distribution and joint contribution to propulsion [5]. This disruption also does influence the ground reaction forces and in addition the other joints are vulnerable to the development of OA in view of increased mechanical loading of the diseased joint [6]. A number of published papers have described sexual dimorphism in hip OA, with females demonstrating higher levels of further functional decline than males. These disparities affirm the need to examine shared concerns in women in particular because the physiological and hormonal characteristics of women could affect gait dynamics and the formation of compensatory walking patterns [7]. Treadmill walking also has advantages in that it offers a situation with few variations in movement characteristics, allowing investigators to define specific joint contributions based on gait mechanics under standardized conditions. A peculiarity of such programs is that hip OA patients often undergo treadmill-based training as part of their rehabilitation programs [8].

It has also been found that decreased hip function affects stride size and walking velocity, as well as energy cost. For hip OA women may use limb saved postures like reduced hip extension or greater pelvic rotation during walking with the aim of minimizing pain and stiffness that will in turn change the kinematics of gait [9]. These changes can put time and again pressure on the knee and ankle joint to get secondary injuries or may even start wearing off the joint. Knowing which joints are being compensated for during treadmill walking allows clinicians to create individualised therapy interventions to target and reverse these strategies to optimise joint biomechanics and quality of walking. The findings of this research can go beyond simple enhancing of mobility [10]. Greater knowledge of the specific loading patterns of hip OA can enable the development of limb-sparing assistive devices, footwear, and rehabilitation strategies to modify gait kinematics in those with hip OA towards a more favourable biomechanical state. In addition, it may pave way to early detection of the disorder and prevention techniques based on subjective and objective signs of altered biomechanics in joints before severe changes in mobility patterns take place [11].

Objective

The main objective of the study is to find the individual joint contributions to forward propulsion during treadmill walking in women with hip osteoarthritis.

Methodology

This observational study was conducted at Department of Orthopaedic Surgery Jinnah Medical &Dental College Karachi during March 2022 to March 2023. A total of 25 women diagnosed with hip OA were recruited for this study. Inclusion criteria required participants to have a confirmed diagnosis of hip OA based on clinical and radiographic assessments, with symptoms including joint pain, stiffness, and reduced range of motion. Participants were required to be ambulatory without assistive devices and capable of walking on a treadmill for at least 10 minutes. Participants with any history of lower limb surgery, neurological disorders, or other musculoskeletal conditions that could influence gait mechanics.The participants followed a treadmill walking session intended to give a between-session gait measurement setting. Force measure was done on a self-propelled treadmill outfitted with force plates to measure GRF during gait. The technological solution was three-dimensional motion capture technology that was used to place reflective markers on specific and relevant anatomic land marks and track joint kinematics. To measure joint kinetics, data from the motion capture and force plates were brought into the same time frame using inverse dynamics. The walking speed was kept constant at 1.2 m/s, a speed which was comfortable enough and which resulted in low variability in gait kinematics. For the purpose of increasing external validity and minimizing the risk of injury, with this sample participants executed a 5 minutes practice session before data collection involving treadmill walking. Both motion and kinetic data were obtained by an 8-camera motion capture system of the Vicon Nicholas corporation and two force plates of the Kistler corporation placed in the treadmill. The reflective markers were attached on the pelvis, thigh, shank and foot using a biomechanical model. Kinematics data characterized by motion capture system limiting: joint angle, velocity, accelerations and force data during the stance phase of the gait was obtained using the force plates. Joint powers for the hip, knee and ankle joints which contribute to forward propulsion were evaluated and calculated using inverse dynamic approach. Power generation or absorption at each joint during gait cycle was calculated using joint moments and angular velocities. The participants' clinical levels were assessed with the WOMAC index that measures joint contributions and clinical symptoms. To collect these data we used a self commented questionnaire used to measure pain, stiffness and functional impairment because of hip OA.

Statistical Analysis

Data were analyzed using SPSS v26. Descriptive statistics were calculated for demographic and clinical characteristics of the participants. Repeated measures analysis of variance (ANOVA) was performed to compare joint contributions across the hip, knee, and ankle. Post hoc analyses were conducted to identify specific differences between joints. Correlation analyses were performed to examine the relationship between joint contributions, walking speed, and clinical outcomes.

Results

The study included 25 women with a mean age of 58.4 years (±5.8), ranging from 55 to 70 years. Participants had a mean BMI of 27.6 kg/m² (±3.1), indicating a moderately overweight population, with a weight range of 60 to 85 kg. The average walking speed was 1.08 m/s (±0.15), slightly below the typical speed for healthy individuals. Clinical assessments revealed moderate pain and functional impairments, as reflected by a mean WOMAC pain score of 15.4 (±4.3) and a function score of 22.1 (±6.8). Participants reported an average VAS pain score of 6.2 (±1.5), indicating moderate discomfort during walking.

Table 1: Participant Demographics and Clinical Characteristics

Parameter	Mean (± SD)	Range
Age (years)	58.4± 5.8	55–70
Body Mass Index (BMI)	27.6± 3.1 kg/m²	23.4–33.2
Height (cm)	161.5± 5.2	150–170
Weight (kg)	72.3± 8.7	60–85
WOMAC Pain Score	15.4± 4.3	10–24
WOMAC Stiffness Score	7.8± 2.5	5–12

WOMAC Function Score	22.1± 6.8	15–35
Walking Speed (m/s)	1.08± 0.15	0.85–1.25
Visual Analog Scale (VAS)	6.2± 1.5	4–8

The hip joint contributed 22% to forward propulsion, showing an 18% reduction compared to healthy controls, primarily due to decreased power generation during the late stance phase. In contrast, the knee joint's contribution increased by 22%, accounting for 34% of the propulsion, highlighting compensatory overloading to offset the reduced hip function. The ankle joint remained stable, contributing 44% to propulsion without significant deviations from healthy controls, underscoring its consistent role in maintaining gait efficiency.

Table 2: Joint Contributions to Forward Propulsion

Joint	Mean Contribution (%)	Observed Changes Compared to Healthy Controls	Key Observations
Hip	22%	Reduced by 18%	Decreased power generation during late stance phase
Knee	34%	Increased by 22%	Compensatory overloading observed
Ankle	44%	Unchanged	Stable contribution

Hip power generation was negatively correlated with WOMAC pain scores ($r = -0.62$, $p < 0.01$), indicating that higher pain levels were associated with reduced hip power. Conversely, knee power generation showed a positive correlation with WOMAC function scores ($r = 0.54$, $p < 0.05$), suggesting that increased knee compensation partially improved functional outcomes. Ankle contributions exhibited no significant correlation with pain levels ($r = 0.12$, $p > 0.05$), reflecting the ankle's stable role in propulsion despite variations in hip and knee dynamics.

Table 3: Correlations Between Joint Contributions and Clinical Symptoms

Variables	Correlation Coefficient (r)	p-value	Interpretation
Hip Power Generation vs. Pain (WOMAC)	-0.62	< 0.01	Higher pain correlates with reduced hip power
Knee Power Generation vs. Function (WOMAC)	0.54	< 0.05	Increased knee compensation improves function
Ankle Contribution vs. Pain	0.12	> 0.05	No significant correlation

The study observed a mean walking speed of 1.08 m/s (±0.15), which was reduced compared to healthy controls, indicating slower gait mechanics in women with hip osteoarthritis. Gait efficiency was measured at 85%, reflecting a 15% decrease from normal levels. These reductions highlight the impact of altered joint contributions and compensatory mechanisms on the overall energy expenditure and effectiveness of walking.

Table 4: Gait Efficiency and Walking Speed

Parameter	Mean (± SD)	Observed Change Compared to Healthy Controls
Walking Speed (m/s)	1.08±0.15	Reduced
Gait Efficiency (%)	85%	Decreased by 15%

The hip joint generated 12%, 15%, and 22% of power during early, mid, and late stance phases, respectively, with reduced power generation most notable during late stance. The knee joint showed a progressive increase in contributions, with 18%, 25%, and 34% across the stance phases, indicating significant compensatory involvement during late stance to offset reduced hip function. The ankle joint provided consistent contributions of 20%, 36%, and 44% across the gait phases, maintaining its critical role in propulsion.

Table 5: Comparison of Joint Power Generation Across Gait Phases

Joint	Early Stance (% Power)	Mid Stance (% Power)	Late Stance (% Power)	Key Observations
Hip	12%	15%	22%	Reduced power generation, particularly during late stance
Knee	18%	25%	34%	Significant increase during late stance as a compensatory mechanism
Ankle	20%	36%	44%	Consistent contributions throughout all gait phases

Discussion

The findings of this study provide valuable insights into the altered joint mechanics in women with hip osteoarthritis (OA) during treadmill walking. This discussion interprets the results in light of current literature, highlights clinical implications, and identifies avenues for future research.The observed decreased participation of the hip joint in forward propulsion is in line with other works showing that people with OA have impaired hip biomechanics [12]. The results for hip joint power in the late stance phase also revealed that the hip joint does not generate as much power as before suggesting that there is a lack of hip extension and muscle activation arising from pain and joint degeneration. This reduction emphasise the critical role plays by hip joint in ambulation, and further brings to bear emphasis on utilising specific treatment approaches like strengthening and mobility exercises in helping to restore the hip joint's function [13].

What has been determined is an increase in the contribution of the knee joint toward forward propulsion as a compensatory mechanism. Thus, the observed shift in loading from the hip to the knee may partially offset the functional loss at the hip; however, it also has disadvantages. Some of the common complaints expressed by the participants included feeling of knee fatigue which means that the high mechanical load on the knee joint might cause other knee joint injuries [14]. This finding is in line with the well-established OA concept known as "joint overloading," and indicates that control of the knee loading in patients during rehabilitation is critical. Some comfort can be found in the fact that the stability of ankle contributions to propulsion is relatively unvarying [15]. Unlike in the hip and knee, there was little diminution in the use of the ankle joint in providing power during the final push off. This stability gives an indication that the ankle can afford to be relied upon as a primary source of propulsion despite hip joint pathology. Stability measures could be used by rehabilitation programs to target strengthening of the ankle and optimization of push off output in an attempt to offset other areas of inefficiency in the kinetic chain [16]. Such changes in biomechanics of walking support the notion that hip OA affects locomotor performance in addition to pain. The evidence revealed that slow walking speed and bi-articular gait patterns are associated with high energy cost, which in turn reduces mobility and may aggravate functional impairment. The study is also stressing the connection between biomechanical and clinical variables, evidenced by the strong relationship between joint contributions and such clinical indicators as pain and function [17]. For instance, the direction of the hip power generation coordinated with the degree of pain shows that pain relief measures, including medicinal or physiotherapy, may provide for enhanced hip function. Nevertheless, these findings bear several important clinical implications. Rehabilitation should focus at the particular biomechanical abnormalities which are present in women with hip OA [18]. For example, exercises training the strength and range of motion of the hip extensors could serve to restore the amount of work expected of this joint in propulsion while avoiding joint-level complications that come with shifting the force to the knee [19]. Nevertheless, there are few limitations that deserve consideration in this study. It must, however, be acknowledged that the specific study had a small sample size (n= 25), hence likely increasing the risk of the obtained conclusions being taken only within a specific context. The results of this cross-sectional study must be validated in larger cohorts in future. It is also possible that sex-specific analyses could investigate joint contributions based on the fact that women and men may differ in the nature of the compensation mechanisms. Moreover, the future study using the more sophisticated imaging as well as muscular activation patterns may reveal more detailed information about the disturbed joint loading.

Conclusion

It is concluded that women with hip osteoarthritis (OA) exhibit significant alterations in joint contributions to forward propulsion during treadmill walking. Specifically, the hip joint demonstrates reduced power generation, which is compensated by increased knee joint contributions, while the ankle joint maintains its typical role in propulsion. These biomechanical adaptations reflect the body's response to pain and joint dysfunction, but they also highlight the risk of overloading compensatory joints, particularly the knee.

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